Science and Modern Civilisation

The Harveian Oration

1897

Sir William Roberts, M.D., F.R.S.


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SCIENCE AND MODERN CIVILISATION

THE

HARVEIAN ORATION

DELIVERED BEFORE

THE ROYAL COLLEGE OF PHYSICIANS

OCTOBER 18, 1897

BY

SIR WILLIAM ROBERTS, M.D., F.R.S.

FELLOW OF THE COLLEGE

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TO

SIR SAMUEL WILKS, BART., M.D., F.R.S.

PRESIDENT OF THE ROYAL COLLEGE OF PHYSICIANS

PHYSICIAN EXTRAORDINARY TO HER MAJESTY THE QUEEN

THIS ORATION IS DEDICATED

WITH SINCERE RESPECT AND ADMIRATION

THE HARVEIAN ORATION

1897

I

Mr. President and Gentlemen,—We have met to-day to commemorate a great name and a great discovery. By his demonstration of the true motions of the heart and blood Harvey laid the foundation of animal physiology as a department of exact science. This work is memorable not only from its historical relation to physiology and practical medicine, but perhaps still more so from its constituting the earliest example of the solution of a biological problem of the first rank by an orderly process of observation and experiment, conceived and carried out on the lines of modern scientific research.

Harvey flourished at the dawn of exact science. Indeed, he was himself one of the heralds of that dawn which in our own time has broadened out into such marvellous day. And I propose, on our present anniversary, to consider Harvey's life and work, not so much as they concern our special studies, but as symbolising the commencement of a new era in human progress—the era of exact science—which, in the present age, is slowly but surely transfiguring the aspects and prospects of civilised society.

I need not long detain you over the particulars of Harvey's life. He was the eldest son of an opulent Kentish yeoman,[1] and was born at Folkestone in 1578.

Harvey passed his schoolboy days at the King's Grammar School in the pleasant city of Canterbury. From thence he migrated, at the age of sixteen, to Caius College, Cambridge. Harvey spent some three years at the University, and graduated as Bachelor of Arts in 1597, just three hundred years ago. At the age of twenty he proceeded to Padua to pursue his medical studies. At that period Padua was one of the foremost universities in Europe, and was especially famous as a school of anatomy. Harvey passed four years at Padua, and had for teachers the most celebrated anatomists of the day, namely, Fabricius of Aqua Pendente and Casserius, names which are still embalmed in our anatomical nomenclature. It was obviously of the greatest advantage to Harvey, in view of his future work, that his attention was thus early fixed on the solid data of descriptive anatomy, which could be directly verified by eye and hand in the dissecting room, rather than on the pedantic aphorisms and cloudy speculations which constituted so large a part of the medical learning of that time. At the end of his course of study at Padua he obtained the degree of Doctor of Medicine, and returned to England in 1603. In the same year he received his doctor's degree from the University of Cambridge. The young Harvey now settled in

[1] In those days the yeomen of Kent were persons of consideration. There is an old rhyme which runs:

A knight of Cales,
A squire of Wales,
And a laird of the North countree
A yeoman of Kent
With his yearly rent
Will buy them up all three.

London, and entered on his professional career amid the most favourable surroundings for commanding success, whether as a fashionable physician or as a scientific investigator. He was in easy circumstances, and he had the prestige attaching to the highest education the time afforded. In his twenty-sixth year he married a daughter of Dr. Lancelot Brown, who had been physician to Queen Elizabeth. This alliance must have brought him in touch with the nobility and Court circles. In addition, he was endowed with a brilliant intellect, a sound character, good health and indomitable industry. To crown all, he was inspired with an enduring passion for original research—a passion which persisted throughout his long life of close on eighty years.

With these manifold advantages, intrinsic and extrinsic, it is not surprising that Harvey made rapid way. At the age of twenty-nine he became a fellow of the College of Physicians; at thirty-one he was elected physician to St. Bartholomew's Hospital; at thirty-seven he was chosen Lumleian Lecturer on Anatomy to the College of Physicians. About the same time he was appointed physician extraordinary to James I. and subsequently physician in ordinary to his successor, Charles I. These latter appointments gave Harvey command of the herds of deer in the Royal parks, for the purpose of the vivisections and dissections which he practised in the course of his researches on the motions of the heart and blood, and in his investigations on animal generation and embryology.

Harvey delivered his first course of Lumleian lectures in 1616, when he was thirty-eight years of age. It was in these lectures that he first propounded his views concerning the motions of the heart and blood, and demonstrated before the fellows of the College the anatomical and experimental evidence on which he based his conclusions. These demonstrations were, as he tells us, annually repeated at the Lumleian lectures for nine or ten successive years, no doubt with ampler and ampler proof of the truth of the new doctrine of the circulation of the blood. It was only after this long and searching probation that Harvey ventured to give his discoveries to the world. This he did in the form of a little treatise, printed at Frankfort in the year 1628. Before proceeding to analyse this remarkable work I will conclude what I have to say, and very briefly, concerning the other work and the rest of the life of Harvey.

After the publication of his treatise on the circulation, Harvey seems to have concentrated himself, as regards physiological work, on his investigations concerning the generation of animals. He bestowed long years and an immense amount of labour on this subject. Over and over again he minutely dissected the organs of generation in various kinds of animals. He watched with patient observation the slow growth of the embryo, from its earliest inception to its full maturity and birth. In this way he gradually accumulated an enormous mass of information which he embodied in fragmentary disquisitions, composed apparently at irregular intervals, as leisure and work permitted. These disquisitions were eventually collected together and printed towards the close of Harvey's life in a separate volume, under the supervision of his friend, Sir George Ent, with the title of 'Exercitationes de Generatione Animalium.' This work, though many times larger than the treatise on the motions of the heart and blood, is incomparably less satisfying and conclusive.

To the modern reader of these disquisitions the reason of their shortcomings is plain enough. Harvey was stopped—and stopped absolutely—at every critical point by his want of a larger magnifying power. He had at his disposal only a pocket lens, which magnified perhaps four diameters. The ovum must have appeared to him as a structureless mass of material, and the seminal discharge as a homogeneous fluid. He knew nothing, and could know nothing, of the cellular elements of the ovum, nor of the motile filaments which constitute the 'vital spark' of the spermatic fluid.

The later years of Harvey's life were passed in peaceful retirement. The civil troubles of the time had broken up his household and scattered his patients, but had left his private fortune unimpaired. At the age of sixty-eight he relinquished his appointments and practice, and went to reside with one or other of his brothers, who were wealthy London merchants. He still continued the studies he loved so well, and maintained his interest in the College of Physicians. Sir George Ent gives us a touching glimpse of him as he appeared in his seventy-third year at the house of his brother Daniel at Combe. 'I found him,' says Dr. Ent, 'with a cheerful and sprightly countenance, investigating, like Democritus, the nature of things. Asking if all were well with him, "How can that be," he replied, "when the State is so agitated with storms, and I myself am yet in the open sea? And indeed, were not my mind solaced by my studies and the recollection of the observations I have formerly made, there is nothing which should make me desirous of a longer continuance. But thus employed, this obscure life and vacation from public cares, which would disgust other minds, is the medicine of mine."'

Harvey had the satisfaction of living to see his great discovery of the circulation of the blood generally accepted as true. In his old age he was known and honoured throughout the learned world. The College of Physicians erected a statue in his honour. In his seventy-sixth year he was elected president of the College, but declined the honour on the plea of the infirmities of age. He accepted, however, the office of councillor, which he held for two years. He enriched the College with many gifts; he furnished the library with books, and filled the museum with 'simples and rarities,' as well as with specimens of instruments used in surgery and obstetrics. Finally, in the year preceding his death, Harvey made a transfer to the College of his paternal estate of Burmarsh, in Kent. In the deed of gift conveying this property to the College there is provision for a salary to the College librarian, and for the endowment of this annual oration. The orator is directed to exhort the fellows 'to search out and study the secrets of nature by way of experiment, and also for the honour of the profession to continue mutual love and affection among themselves.' This double injunction of our venerated saint and apostle has, I venture to believe, been fairly observed, according to the measure of their abilities, by successive generations of the fellows of this College, even to the present day.

Harvey made a peaceful ending in his eightieth year, and was buried, full of years and honour, in his brother Eliab's vault in the parish church of Hempstead, near Saffron Walden, in Essex. Seventeen years ago, on October 18, 1883, by the piety of this College, his remains were removed from the dilapidated vault, and, with befitting solemnity, reinterred in a marble sarcophagus in the Harvey Chapel attached to the same church.

II

Harvey's activity as an investigator ranged over a wide field, but his fame as a discoverer and his rank in the hierarchy of science must always depend on his researches on the motions of the heart and blood. These researches were published in 1628 in the form of a small Latin quarto of only seventy-six pages. This little volume embodies the results of some twenty years' work, carried on during Harvey's prime, when his inventiveness and receptivity were at their highest. The book is in several respects a remarkable one. It presents to us the earliest record we possess of a really scientific investigation in the domain of biology, based on observation and experiment. Although written 270 years ago, the work is essentially modern in tone and method. It is, in fact, the prototype of the scientific 'paper' or 'monograph' of our own day; and for clearness of demonstration and conclusiveness of proof stands favourable comparison with the most renowned masterpieces of recent times.

Harvey begins with an account of the state of knowledge on his subject at the time he wrote. He describes the confusion and contradiction reigning in men's minds concerning the actions and offices of the heart and the movements of the blood. He then sets forth in a series of chapters the dissections, vivisections, observations, experiments, and reasoning by which he proved that the blood flows in a continuous stream along its now well-known route. He shows that the motor power for the movement of the blood resides in the heart, that the heart is a muscular organ, and that the auricles and ventricles are hollow muscles which contract in action and forcibly expel their contents. He demonstrates that the disposition of the valves within the heart, and at the roots of the aorta and pulmonary artery and along the veins, is such that the blood expelled by the contractions of the heart must of necessity flow onward in the direction indicated, and that any reflux in a contrary direction is a mechanical impossibility. He argues that the blood-stream must be continuous throughout its whole course, because, wherever you tap the channel, whether in an artery or in a vein, the whole of the blood contained in the body is drained away in a few minutes. He fortifies his argument by a number of collateral proofs, all converging and pointing to the same unavoidable conclusion. Especially ingenious and original is the following argument, which has a curiously modern ring about it. If you estimate the charge of blood delivered into the arteries at each stroke of the ventricle at one or two drachms, and calculate the rate at which the heart is beating at 60 to 70 per minute, you arrive at a volume of blood passing through the heart in the course of every half-hour which is greater than the aggregate ingesta of a whole day, and greater than the total sum of blood contained in the body. The inference is therefore irresistible that the whole of the blood, and the same blood, must be incessantly passing and revolving through the heart.

Harvey was much exercised as to the precise way in which the blood found its way from the terminal arteries to the commencing veins. He had absolute proof before him that it did somehow find its way, but how? He was able, by minute dissection of the organs and tissues, to satisfy himself that it was not, as some of his contemporaries supposed, by coarse anastomosis between the arteries and veins. 'I have myself,' he tells us, 'pursued this subject of the anastomosis with all the diligence I could command, and have given not a little both of time and labour to the inquiry; but I have never succeeded in tracing any connection between arteries and veins by a direct anastomosis of their orifices. Neither in the liver, spleen, lungs, kidneys, nor any other viscus is such a thing as anastomosis to be seen; and by boiling I have rendered the whole parenchyma of these organs so friable that it could be shaken like dust from the fibres, or picked away with a needle, until I could trace the fibres of every subdivision, and see every capillary filament distinctly.'[1] Harvey, with his simple lens, could not detect the delicate capillary network which united the minute arteries and veins into a closed vascular system; and he was reduced to the conjecture that the blood percolated the organs and tissues as water percolates the earth and produces springs and rivulets. It is almost pathetic to contemplate this eager earnest inquirer, looking with wistful, straining eyes for the communicating channels which he knew must exist, but could not see, and to remember that the solution of the puzzle was almost within his grasp; for hardly had he closed his eyes than the improvements in the microscope enabled Malpighi and Leeuenhoek to demonstrate the completion of the circuit of the blood through the capillaries in the web of the frog's foot.

It is singular that Harvey in all his writings nowhere betrays any consciousness of his sore want of a higher magnifying power. He did not, apparently, divine that it was possible to enlarge objects beyond

[1] Works, p. 103.

the power of the common lens which had been in use from antiquity; yet it was precisely this want which foiled him at almost every step in the prosecution of the studies to which he devoted his life.

III

When Harvey was entering on his career as an investigator, in the early years of the seventeenth century, the great movement of the Renaissance had produced its full effects. Starting in Italy in the fourteenth century, it spread during the fifteenth and sixteenth centuries and permeated the rising nationalities of Western Europe. It was through the zeal engendered by this movement that the priceless literary and artistic treasures of Greece and Rome were rescued from oblivion and made the secure heritage of all time. The study of these monuments of ancient genius, and the inspiration communicated by them, saved mediæval Europe from barbarism, and created a new civilisation not inferior in polish to that of the classical ages. Upon literature and the fine arts the spirit of the Renaissance reacted with the happiest possible effects. It inspired the masterpieces of poetry, painting, architecture, and sculpture, which constitute the glory of the fifteenth and sixteenth centuries, and compel the admiration and challenge the rivalry of the nineteenth century. But, as regards natural knowledge, the influence of the Renaissance was at the first, and even for a long time, distinctly unfavourable. The writings of Hippocrates, Aristotle, Ptolemy, Galen, and other masters were studied and searched, not for inspiration to new inquiry and higher development—but these great names were erected into sacrosanct authorities, beyond whose teaching it was vain, and even impious, to seek to penetrate. The result of this perversion was that the pursuit of natural knowledge degenerated into sterile disputations over the words of the masters. This numbing despotism of authority comatosed the intellect of Europe during many generations. It received the first rude shocks from the discoveries of the great anatomists of the sixteenth century; and it was finally overthrown by the force of the demonstrations of Galileo and Harvey—powerfully aided, no doubt, by the philosophical writings of Bacon and Descartes.

These four men—Galileo, Harvey, Bacon, and Descartes—were the dominating spirits of their epoch in the sphere of natural knowledge; they were contemporaries; and three of them must have had more or less personal acquaintance with each other. Harvey was Bacon's friend and physician; and we can easily believe that much talk went on between the investigator and philosopher concerning the studies in which they were mutually interested—and that Bacon imbibed his enlightened notions respecting the importance of experiments in the pursuit of knowledge from the precepts and practice of Harvey. It does not appear that Descartes was personally known to Harvey, but he was one of the earliest to accept the doctrine of the circulation, and to write in its defence. When Harvey was a student at Padua, Galileo occupied the chair of mathematics in that university. These two men take rank as the twin founders of modern science—the one in the domain of biology and the other in the domain of physics. Their lives largely overlapped; they were contemporaries for sixty-four years, and both nearly reached the patriarchal age of fourscore. Roughly speaking, their period of activity covered the first half of the seventeenth century. They were, each in his respective department, pioneers in the method of searching out the secrets of nature by observation and experiment, and in proclaiming the paramount necessity of relying on the evidence of the senses as against the dicta of authority.

IV

The present year is the 300th anniversary of Harvey's graduation at Cambridge, and of the commencement of his career as a student and investigator of nature. That date, 1597, corresponds roughly with the birth-time of modern science. The occasion is, therefore, not inappropriate for a survey of the changes impressed upon civilised society by science—after three centuries of expansion and growth. The lapse of time is sufficiently long, and the advance made is sufficiently great, to enable us to estimate approximately the scope and strength of this new factor in our environment; and perhaps even to appreciate the influence which the cultivation of science is likely to have on the future of modern civilisation.

All the older civilisations have issued either in extinction, or in permanent stagnation. The civilisations of Egypt and Chaldæa and of Greece and Rome, after a phase of progressive decline, eventually perished by military conquest. The ancient civilisations of the Far East—those of India and China—still persist, and have a semblance of life; but it is a life of helpless torpor and immobility. Is our modern civilisation doomed to share a kindred fate? There are, I think, good reasons for believing that in this respect history will *not* repeat itself. Special features are observable, and special forces are at work, in contemporary civilisation which differentiate it profoundly from all its predecessors.

It may be said, broadly, that the older civilisations rested essentially upon art and literature (including philosophy)—and that modern civilisation rests, in addition, upon science and all that science brings in its train. This distinction is, I think, fundamental—and connotes a radical difference as regards stability and continuance between ancient and modern society. A comparison of the mode of growth of the fine arts and literature on the one hand, with the mode of growth of science and its dependent useful and industrial arts on the other, brings out this point very clearly.

The evolution of literature and art displays the following well-marked characteristics. Starting from some rude beginnings, each branch of literature and each branch of the fine arts grows by a succession of improved ideals until a certain culminating level of excellence (or phase of maturity) is attained. When this level is reached no further growth takes place, nor even seems possible. The level of excellence attainable by any nation depends presumably upon the measure of the original endowment of the race with artistic and literary faculty. When and after this summit level of excellence is achieved, all subsequent expansion, if any, is quantitative rather than qualitative—and consists in modifications, variations, repetitions and imitations—but without any real advance in artistic and literary excellence. It may be further noted that there is observable in the past annals of literature and the fine arts a fatal tendency to a downward movement. The variations are apt to show meretricious qualities—which indicate, in the judgment of critics, a degradation from the high standard of the earlier masters. The life of each of the fine arts seems, as Professor Courthope has expressed it, to resemble the life of an individual in having periods of infancy, maturity, and decline. The witness of history bears out this view.

It is almost startling to consider how long ago it is since most branches of art and literature had already reached their highest known pitch of excellence. The Homeric poems are supposed to have been composed a thousand years before the Christian Era—and no one doubts that as examples of epic poetry they still stand in the front rank. In the fourth and fifth centuries B.C. there occurred in Greece an extraordinary outburst of artistic and literary genius—such perhaps as the world has never seen before nor since. During this epoch sculpture was represented by Phidias and Praxiteles—architecture by the builders of the Parthenon—painting by Apelles and Zeuxis—dramatic poetry by Sophocles, Euripides, and Aristophanes—and speculative philosophy by Plato and Aristotle. Greece maintained her political independence for two centuries after this period; but she did not produce anything superior, nor apparently even equal, to the masterpieces of this golden age.

A parallel sequence is observable in the history of Ancient Rome. Art, literature, and philosophy—and all studies that may be grouped under these headings—attained their culmination in the Augustan age; and no advance thereupon took place, but rather a falling off, during the subsequent centuries of imperial Rome's political existence.

If we turn our eyes to the Far East we see that the masterpieces of architecture and ornamental metal work, and of poetic and philosophical literature are all old—many of them very old. Neither in India nor China nor in any other Far Eastern country are there any indications of advance for many centuries in the domain of artistic and literary culture.

The history of Western Europe tells a similar tale. The finest examples of Gothic and Norman architecture date from the twelfth and thirteenth centuries. Painting culminated in Italy during the fifteenth and sixteenth centuries with Raphael, Da Vinci, Correggio, Titian, and Paul Veronese. The same art reached its highest level in the Low Countries with Rembrandt and Rubens—in Spain with Velasquez and Murillo—in France with Claude Lorraine and Poussin—all artists who flourished in the seventeenth century. In England nothing greater than the works of Reynolds, Gainsborough, and Turner has been produced by later artists. Similarly with literature : most of the masterpieces belong to a past age. Italy can show no higher examples of poetry than the creations of Dante, Petrarch, Tasso, and Ariosto. The most ardent admirers of the Victorian poets would scarcely contend that any of them stand on a higher pedestal than Shakespeare and Milton ; nor would any German critic claim equality for any recent poet of the Fatherland with Goethe and Schiller. In the delightful art of music, the masterpieces of Haydn, Handel, and Mozart, judging by their popularity at the present day, are not surpassed by the works of any of the later musical composers.

I need not pursue the subject in greater detail. Wherever we look—in all ages, among all peoples—we encounter the same story with regard to that large and varied and most precious outcome of the human mind which may be grouped under the categories of the fine arts and literature. There is a history of improvement and growth up to a certain culmination, or phase of maturity. Beyond that point no further growth seems possible—but rather, instead, a tendency to decline and decadence.[1]

The evolution of science differs fundamentally from that of literature and the fine arts. Science advances by a succession of discoveries. Each discovery constitutes a permanent addition to natural knowledge—and furnishes a post of vantage for, and a suggestion to, further discoveries. This mode of advance has no assignable limits; for the phenomena of nature—the material upon which science works—are practically infinite in extent and complexity. Moreover, science creates while it investigates; it creates new chemical compounds, new combinations of forces, new conditions of substances, and strange new environments—such as do not exist at all on the earth's surface in primitive nature. These 'new natures,' as Bacon would have called them, open out endless vistas of lines of future research. The prospects of the scientific inquirer are therefore bounded by no horizon—and no man can tell, nor even in the least conjecture, what ultimate issues he may reach.

The difference here indicated between the growth of art and literature and the growth of science is, of course, inherent in the subjects; and is not difficult to explain.

[1] If we take a wider view of the constituent elements of organised society—and embrace in our consideration the religious systems, the political and civil institutions, the military organisations, the commerce and the miscellaneous disconnected mass of natural knowledge existing in the older civilisations—we look in vain for any constituent which had more than a limited scope of expansion, and was not subject to decay.

The creation of an artist, whether in art or literature, is the expression and embodiment of the artist's own mind—and remains always, in some mystic fashion, part and parcel of his personality. But a scientific discovery stands detached; and has only a historical relation to the investigator. The work of an artist is mainly subjective—the work of a scientific inquirer is mainly objective. When and after a branch of art has reached its period of maturity, the pupil of a master in that art cannot start where his master ended, and make advances upon his work; he is fortunate if at the end of his career he can reach his level. But the pupil of a scientific discoverer starts where his master left off; and, even though of inferior capacity, can build upon his foundations and pass beyond him. It would seem as if no real advance in art and literature were possible except on the assumption that there shall occur an enlargement of the artistic and literary faculty of the human mind. No such assumption is required to explain and render possible the continuous advance of science. The discoverer of to-day need not be more highly endowed than the discoverer of a hundred years ago; but he is able to reach further and higher because he stands on a more advanced and elevated platform built up by his predecessors.

V

The fatal weakness of. previous civilisations lay in the absence of any element which had inherent in it the potentiality of continuous growth and unlimited expansion—and this is precisely what exact science supplies to modern civilisation. A sharp distinction must be drawn between the so-called science of antiquity and the science of to-day. The ancients had a large acquaintance with the phenomena of nature, and were the masters of many inventions. They knew how to extract the common metals from their ores; they made glass; they were skilled agriculturists; they could bake, brew, and make wine, manufacture butter and cheese, spin, weave, and dye cloth; they had marked the motions of the heavenly bodies, and kept accurate record of time and seasons; they used the wheel, pulley and lever; and knew a good deal of the natural history of plants and animals, and of anatomy and practical medicine. This store of information had been slowly acquired in the course of ages—mostly through haphazard discovery and chance observation—and formed a body of knowledge of inestimable value for the necessities, conveniences, and embellishments of life. But it was not science in the modern sense of the word.[1] None of this knowledge was systematised and interpreted by co-ordinating principles; nor illuminated by generalisations which might serve as incentives and guides to further acquisitions. Such knowledge had no innate spring of growth; it could only increase, if at all, by casual additions—as a loose heap of stones might increase—and much of it was liable at any time to be swept away into oblivion by the flood of barbaric conquest.

It is quite obvious, from the subsequent course of events, that there came into the world of natural knowledge about three centuries ago, in the time of Galileo and Harvey, a something—a movement, an impulse, a

[1] 'It is not a collection of miscellaneous, unconnected, unarranged knowledge that can be considered as constituting science.'—*Whewell.*

spirit—which was distinctly new—which Bacon, with prophetic insight, termed a 'new birth of time.'

This remarkable movement did not originate with any startling revelation; it consisted rather in an altered mental attitude, and a method. There arose a distrust in the dicta of authority, and an increasing reliance on ascertained facts. These latter came to be regarded as the true and only data upon which natural knowledge could be securely founded and built up. Doubt and question took the place of false certainty. The hidden meaning of phenomena was sought out by observing them under artificially varied conditions—or, to use the words of Harvey, 'the secrets of nature were searched out and studied by way of experiment.' *À priori* reasoning from mere assumptions, or from a few loosely observed facts, fell into discredit. Observations were repeated, and made more numerous and more exact. These were linked together with more rigid reasoning to stringent inductions. Hypotheses (or generalisations) were subjected to verification by experiment; and their validity was further tested by their efficacy in interpreting cognate problems and by their power to serve as guides to the acquisition of fresh knowledge. Instruments of precision were devised for more accurate observation of facts and phenomena—for weighing and measuring, for estimating degrees of temperature, the pressure of gases, the weight of the atmosphere, and for recording time. The sense of sight was aided by means of the telescope and microscope. The invention of instruments and appliances for assisting research was an essential and invaluable feature of the 'new philosophy.' It is singular that so little progress in this direction was made by the quick-witted Greeks of the classical period; and their neglect or incapacity in this respect largely accounts for their conspicuous failure in science as contrasted with their brilliant success in art and literature.[1]

VI

The new method soon began to yield fruit—at first slowly, then more and more rapidly as the workers increased in number, and the method was more fully understood. Discoveries were no longer solely stumbled on accidentally, but were gathered in as the fruit of

[1] Whewell observes (*History of the Inductive Sciences*, vol. i. book 1, chap. iii.): 'The Aristotelian physics cannot be considered as otherwise than a complete failure. It collected no general laws from facts; and consequently, when it tried to explain facts, it had no principles which were of any avail.' Whewell argues that this failure was not due to the neglect of facts. He goes on to say: 'It may excite surprise to find that Aristotle, and other ancient philosophers, not only asserted in the most pointed manner that all our knowledge must begin from experience, but also stated in language much resembling the habitual phraseology of the most modern schools of philosophising, that particular facts must be *collected*; that from these general principles must be obtained by *induction*; and that these principles, when of the most general kind, are *axioms*.' Then he quotes passages in proof from Aristotle's writings. It is, however, pretty evident that Aristotle's reverence for facts was no more than a pious opinion, which he habitually ignored in the actual handling of questions of natural knowledge. His treatise 'On the parts of Animals' bristles with errors of observation which a very moderate amount of painstaking would have rectified. Had the ancient Greeks, and their successors in the middle ages, been more accurate observers of facts, and had they sought for and invented instruments for the more exact observation of facts, they would not have so conspicuously failed to establish at least the foundations of exact science. The historian of the inductive sciences, however, will have it otherwise. He sums up his argument thus: 'The defect was that, although they had in their possession Facts and Ideas, the Ideas were not distinct and appropriate to the Facts.' Is it not rather the case that the 'Ideas were not distinct and appropriate to the Facts,' precisely because the 'Facts' were indistinctly seen and imperfectly apprehended?

systematic observation and purposive research. It is not necessary for me, even if I had the time and ability, to trace the history of scientific discovery from the time of Harvey onward. I will only mention a few particulars by way of illustration. You all know how, as time passed on and knowledge expanded, the primary sciences became divided into separate departments for more minute study—how new sciences have arisen, some of which have now grown to vast proportions—how improved instruments and appliances of infinite delicacy have been invented to aid research —and how, in the present age, the gains of pure science have been turned to innumerable channels of practical utility.

The advances made in physics and mechanics during the seventeenth and eighteenth centuries prepared the way for the invention and perfection of the steam-engine in the nineteenth century. The introduction of the steam-engine increased at a bound the power of the human arm many-fold.[1] Through its instrumentality the land has been covered with railways, and the sea with ocean steamers. Electrical science has given us the telegraph and telephone, a new illuminant, and a new motor. The steam printing press, the telegraph, and the railway together, have made it possible to produce that perhaps most wonderful of all the indirect outcomes of the growth of science—the modern newspaper. The great science of chemistry has revealed the composition of the material world ; has originated vast industries, which

[1] Mr. Mulhall calculates that ‘ our steam-power in the United Kingdom is equal to the force of 169,000,000 able-bodied men, a number greater than the whole population of Europe could supply.’—*National Progress during the Queen's Reign*, p. 22.

give work and wages to millions of the population ; and has placed all kinds of manufacturing processes upon a basis of scientific precision. Under cover of chemistry have sprung up the sub-sciences of photography and spectroscopy, which have given a new and unexpected development to our knowledge of the heavenly bodies. The revelations of palæontology and embryology have led to the establishment on a firm basis of the theory of organic evolution. This theory—by far the most penetrating generalisation of our time—has not only thrown a flood of light upon the deepest problems of natural history, but has also revolutionised the whole domain of speculative thought. Physiology and practical medicine have profited immensely by the general advance of the sister sciences, and by the adoption of scientific methods in the prosecution of research. Optical science gave birth to the achromatic microscope. The microscope has laid bare the minute structure of plants and animals, and introduced zoologists and botanists to a vast sub-kingdom of minute forms of life, previously undreamt of. The microscope also, in conjunction with chemistry, founded the new science of bacteriology. Bacteriology has inspired the beneficent practice of antiseptic surgery ; it has also discovered to us the parasitic nature of zymotic diseases—and opened out a fair prospect of ultimate deliverance from their ravages.

Thus have the several sciences advanced, and are still advancing, in concert, step on step, by mutual help, at an ever-increasing speed—pushed on by that irrepressible forward impulse which has characterised the scientific movement from its inception. This movement has now become the dominant factor in civilisation.

VII

There is no doubt that, under the reign of science, a striking amelioration in the state of society has taken place. The mass of the people are better housed and fed—and, above all, better educated. Their sanitary surroundings are improved, and the death-rate has fallen. Crime and pauperism have diminished, and there is greater security for person and property. The amenities and enjoyments of life are on the increase, and the average scale of comfort is markedly raised. Moreover, this amendment is not confined to the material and physical well-being of the population. There is some evidence that the complex of conditions we term 'modern civilisation' is acting favourably in the direction of making people more reasonable, and better conducted. Peace is now the normal condition between civilised states; and there is a growing trend of opinion in favour of settling international differences by the more rational method of arbitration, rather than by war. Political morality approximates more nearly to that recognised as proper in private life. The duel has almost been laughed out of court. Industrial quarrels are conducted with more order; there is an appeal to facts and reason on both sides, and more readiness to adjustment by compromise.

The whole environment of modern life seems in several ways calculated to foster habits of correct thinking and acting. The inclusion of science in the scope of general education is a very important innovation. This extends the range of subjects in regard to which precise reasoning is possible; and tends to promote the application of scientific modes of thinking and reasoning to all the problems of life. We may be quite sure that exact thinking leads in the main to correct conduct; an evil deed is not only a crime, but also a blunder. The periodical press must, one would think, be a good training-school for thinking and reasoning. The discussion of all sorts of questions in its columns can scarcely fail to have an educating effect. The disputants must perforce read one another's arguments and be, consciously or unconsciously, influenced thereby. It may be assumed, or at least hoped, that there is in arguments, as in organic forms, a tendency to the survival of the fittest—and that in the long run the better argument carries the day. The blaze of publicity amid which we live, through the ubiquitous newspaper, lends an additional motive to right doing. The 'fierce light which beats upon a throne' beats nowadays also upon the citizens, and doubtless helps to keep them in the straight path.

But, say the prophets of evil: 'This will not endure; modern civilisation, based on science, will in time go the way of all its predecessors, and end in extinction or in decay and stagnation.' It is proverbially unsafe to dogmatise about the future; and in all human affairs, even those termed scientific, there is nothing so certain as the unexpected. This, however, may be affirmed: that if modern civilisation is to come to an end, it will not perish in the same way, nor from the same causes, as previous civilisations.

One of the standing perils of civilised communities in ancient times was the risk of being subjugated by less civilised neighbours, or of being overwhelmed by hordes of barbarian invaders. This danger no longer threatens us. Power has passed for ever into the hands of the nations which cultivate science, and invent. The appliances of war are now placed on a scientific basis; and the issue of battle is decided in the laboratories of the engineer and chemist. The late C. H. Pearson argued that the dark and yellow races, in virtue of their greater number and fecundity, might in time come to dispute the supremacy of the white races—that they would learn the drill and copy the armaments of European armies, and thus equipped would be able, by their superior mass, to hem in and curb, if not to subjugate, the Western nations. But the march of science and invention never stops; and it is inconceivable that the scientific nations shall not always be many stages in advance of the unscientific nations in the destructiveness of their weapons and the perfection of their military equipments—and this would give them an advantage which scarcely any disparity of numbers could neutralise. The 'yellow terror' can never be more than a phantom until these races begin to show capacity for scientific discovery, and the further (and somewhat different) capacity for turning their discoveries to practical uses.

Against the more insidious peril of decay and stagnation the scientific movement seems also to offer effective safeguards. We sometimes hear complaints of the hurry and bustle—the stress and strain—of modern life; this unrest may incommode individuals—but it is the antiseptic of society. Probably the deadliest predisposing factor in the decline of former civilisations was the mental inanition arising from deficiency of fresh and varied intellectual pabulum. Physiological analogies lead us to the inference that an idle brain, like an idle muscle or an idle gland or nerve, would deteriorate in function; and, conversely, that a well-exercised brain would tend to reach its possible best.

I conceive that our forefathers and the ancients, for the most part, led somewhat monotonous lives. They had but little fresh and varied food for thought. The generality could not, for lack of 'news,' take a sustained interest in the course of public events. The world of science was an unopened book. Intercommunication was slow and difficult; and the whole current of existence flowed sluggishly. Contrast this with the vivid abounding life of the present day. Veins of interest are greatly multiplied—to meet and satisfy the infinitely varied individual aptitudes of men and women. A considerable number of persons of both sexes now busy themselves, either as amateurs or something more, with the study of some branch of science or natural history. Those whose bent is to politics, art, letters, sport, or fashion find in the daily newspaper and the periodical press an unfailing fresh supply of the mental food they love. Business and pleasure are carried on with a briskness formerly unknown, and the pulse of national life is quickened through every part. It seems impossible that decay should invade the body politic while such conditions of all-pervading activity prevail—and there is no valid reason why these conditions should not continue to prevail. It has often been remarked that periods of national upheaval, when men's minds are deeply stirred—like the rise of Islam, the Protestant Reformation, and the French Revolution—were exceptionally prolific of able men. It does not appear altogether unreasonable to suppose that the stir and movement of modern life may be similarly favourable to the production of 'men of light and leading' for the service of the community. The proximate cause of the downfall of states seems always to have been a defective supply of strong and capable men at the head of affairs, and in positions of trust. The *dolce far niente* is not conducive to the formation of strong characters; and those who sigh and yearn for social quietism may find comfort in the reflection that the hum and buzz which disturbs them is a sure token of the health and strength of the common hive.

Gentlemen,—It is given to few to deliver a stroke of work like that of Harvey. But many of those before me have done something, and some a great deal, to forward the beneficent march of science. To lift the veil from even the smallest corner of the unknown in nature is not only a pure delight but is surely also doing a service in the cause of humanity. We are here to-day all disciples of Harvey—paying willing homage to his great name. And though we cannot pretend to his genius, we can all of us take to heart the lesson of his life—and seek to emulate his gentleness, his patient industry, his single-minded devotion to a high purpose, and his unswerving loyalty to truth.

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